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MECHANICAL AND THERMAL CHARACTERISTICS OF STIR CASTED NANO COMPOSITES BASED ON LM 9 GRADE ALUMINIUM WITH A REINFORCEMENT OF MULTI WALLED CARBON NANOTUBES NANOCOMPOSITES

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ABSTRACT

This paper is intended to study mechanical, corrosion and thermal properties of aluminium metal matrix composites with Multiwalled carbon nanotubes as reinforcements. In the present study, aluminium base alloy (LM 9) is reinforced with multi-walled carbon nanotubes (MWCNTs) in 1%, 2 and 3 % using stir casting. Tests are conducted to evaluate for hardness, thermal behavior under varying temperature, and thermal conductivity to assess the influence of MWCNTs as reinforcements. The results indicate that Aluminium – MWCNTs composites possess improved mechanical properties. DSC thermographs indicate that there is no change in the thermal behavior of the composites under varying temperature conditions. Thermal conductivity measured using hot disc thermal analyzer showed a marginal reduction in the thermal conductivity due to increase in density of microstructure and resulting improved hardness.

KEYWORDS: Aluminium, Multi-Walled Carbon Nanotubes, Composite; Hardness, DSC & Thermal Conductivity

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Original Article

1. INTRODUCTION

Metal Matrix Composites (MMCs) are envisaged as replacements to conventional metals and alloys owing to their special properties. They find application in marine, aerospace and automobile sectors. Metal matrix composites are metallic alloys reinforced with other materials to give extra strength ductility, hardness. Among several materials, aluminium alloy is used in versatile applications and focus of the researchers has been to develop cost effective and improvised aluminium composite that possess high tensile strength, good corrosion resistance, tribological properties etc. Several reinforcements like Al_2O_3, TiC, SiC, SiO_2, B_4C, Al-N were the most common materials used by different authors [1-30] for property enhancement of aluminium. In recent years, carbon nanotubes (CNT's which are allotropes of carbon have been selected to create low weight self-lubricating metal matrix nanocomposites owing to their lubricious nature. It was established that they possess improved mechanical and tribological properties. Besides, they also have characteristics like high electrical, mechanical, and thermal properties appropriate for many applications. Due to their greater surface area, nano materials in smaller quantities can be used as reinforcements that produce noticeable results in the properties of the composites. Reinforcement of carbonaceous nano materials were proved to have also increased optical & di-electric properties. The mechanical

properties of hardness and wear resistance also improved significantly. Current studies[1-19] were devoted to employ nano scale graphite, multiwalled carbon nanotubes (CNTs) to attain upgraded properties.

1.1 Present Investigations on Aluminium Multi Walled Carbon Nanotube Composites

The intention of this study is to explore the behavior of Aluminium–Multi walled carbon nanotube composites in terms of mechanical and thermal properties. In the present study, the Aluminium - MWCNT composites were prepared by stir casting technique to obtain uniform and dense structure. The Multiwalled carbon nanotubes reinforcements are dispersed in the aluminium (LM9) material in 1, 2 and 3 weight %. Micro hardness is measured at different concentration of MWCNTs and the improvement of hardness on thermal conductivity is assessed. Thermal conductivity is assessed by hot disc method. The weight fraction is limited to 3 %, since most of the studies mentioned earlier found that as the mass fraction increases beyond a limit it will lead to brittleness leading to degradation of mechanical properties.

2. MATERIALS AND METHODS

Multi-walled carbon nano tubes produced by CVD method were purchased from M/s Cheaptubes Inc., USA. The MWCNTs are of 30-50 nm diameter, 1 to 25 micrometers length and 97 % purity. Light metal 9 grade Aluminium is selected as base materials for dispersion with nano materials.

2.1 Preparation of Nano Composites

The composites were manufactured by reinforcing LM 9 grade aluminium with MWCNTs using stir casting technique. Aluminum bar (LM 9 grade) was put into the crucible melted to a temperature of 700 ºC and MWCNTs was added to the molten metal and mixed carefully using a stirrer to confirm uniform distribution. The metal was removed after for 5 min of stirring and was cast into bars as specimen.

2.2 Preparation of Nano Materials Prior to Dispersion in Aluminium

As received multi-walled carbon nanotubes are highly agglomerated and require processing to separate individual tubes. Figure 1 a & b show as received Multiwalled carbon nanotubes and disentangled MWCNTs using solvent respectively. Figure 1a show highly agglomerated MWCNTs which are unsuitable for dispersion as reinforcements. Multiwalled carbon nanotubes were sonicated in hexane to untangle the individual tubes prior to dispersion

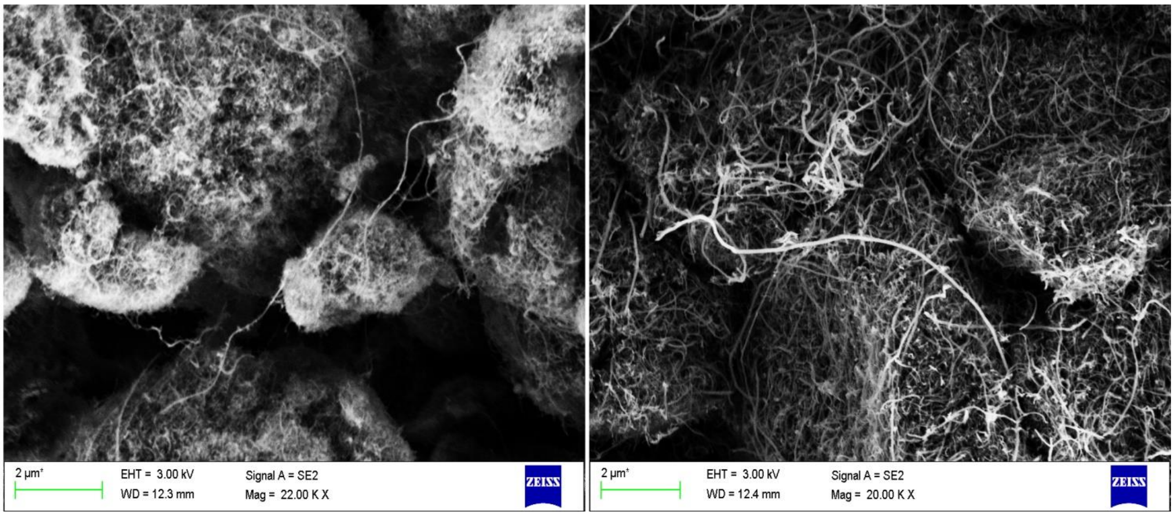

Figure 1: FESEM Images of Multi Walled Carbon Nanotubes (a) Pristine MWCNTs (b) Purified MWCNTs.

This step ensures uniform dispersion of MWCNTs in the composite. It can be observed from Figure.1 b that the MWCNTs could be separated into individual tubes which when added to the produces of uniformly distributed composite.

2.3 Mechanical Properties

Mechanical property improvement of the composites is determined in terms of their micro hardness. Micro hardness test (ASTM E 384) defines the hardness of a material to wear and tear. To measure micro hardness, 300 gf load is applied at 10 positions on the specimen and the average value is reported as hardness of the material.

2.4 Thermal Analysis

Differential Scanning Calorimetry (DSC) is employed as a screening tool to follow the aging sequence of base aluminium and aluminium – MWCNT composites. DSC processes the change in the rate of heat flow of samples as a function of temperature or time. Through observations of the changes in flow rate of heat between the sample and its reference materials, DSC can detect the quantity of heat absorbed during these transitions. This technique can predict the thermal stability of metals and their estimated life time under thermal loading.

The thermal conductivity is measured by Hot Disk method which eliminates errors while measuring liquid thermal conductivity. Kapton sensor 7577 was selected for testing while keeping short measurement time to reduce convection. Three sets of experiments with different measurement times were conducted on the samples and the mean values are stated.

3 RESULTS AND DISCUSSIONS

3.1 Characterization of the Structure of Composites on HRSEM

To characterize the microstructure of the composite, the specimen of size 10mmx10mm were etched and characterized using an FESEM. SEM micrographs portraying the surface of the composite are noted with ancillary electron image mode at 15kV and 30kV and are shown in Figure.3.

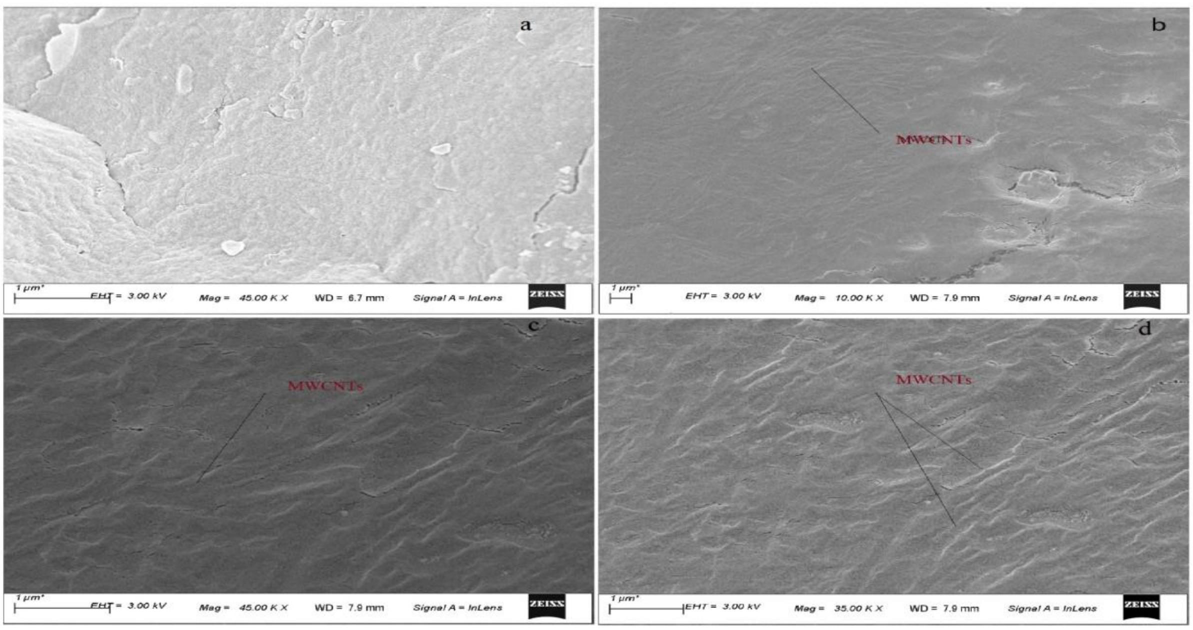

Figure 2: FESEM Micrographs of (A) LM 9 Aluminium (B) Aluminium + 1 % MWCNTs (C) Aluminium + 2 % MWCNTs (D) Aluminium + 3 % MWCNTs

Even dispersion of aluminium matrix with MWCNTs intensely determines the Mechanical properties. Figure 2 portrays the micro structure of base aluminium and aluminum reinforced with MWCNTs. From Figure 2 b, in case of aluminium dispersed with 1 % MWCNTs, the nano tubes were established to be dispersed well alongside the periphery of the grain and detached from the original cluster. Figure 2c & d show the cases of 2% and 3% MWCNTs dispersed in aluminium and it may be perceived that the MWCNTs were uniformly scattered throughout the surface irrespective of the grain boundary. Further, as the percentage of MWCNTs increase, the density of the structure is found to have improved and this would effect in improved properties of composite.

3.2 Hardness

Hardness of composite is a vital requirement for use in automotive parts. The micro hardness values of base metal and aluminium metal matrix composites at varying weight fractions of MWCNTs is tested and tabulated in Table 1.

Table 1: Micro Hardness of Composites

Specimen	Micro hardness (HV)
Aluminium (LM 9) specimen	65
Aluminium (LM 9) + 1 % MWCNTs	115
Aluminium (LM 9) + 2 % MWCNTs	150
Aluminium (LM 9) + 3 % MWCNTs	180

There is a progressive upsurge in the micro hardness values with a reinforcement of MWCNTs in aluminium. Due to improved reinforcements of MWCNTs in Aluminium and due to preprocessing of MWCNTS, micro hardness values are far better than normal values. The relative density also improved with reinforcement of MWCNTs thus improving the hardness of the composites.

3.3 Analysis on differential Scanning Calorimetry

Differential Scanning Calorimetry is an extensively used technique for the thermal analysis of lighter metals like Aluminum based metal matrix composites alloys. The DSC curve in Figures 3 & 4 shows heat flow as a function of temperature and time respectively. The figures depict that Aluminium – MWCNTs composite is slightly more intense than that of base aluminium. Nevertheless, the outline of the both curves is superimposed suggesting mild influence of MWCNTs. Except for a difference in the crystallization temperature, the difference between the thermal performance of base aluminium and aluminium – MWCNTs composite is similar.

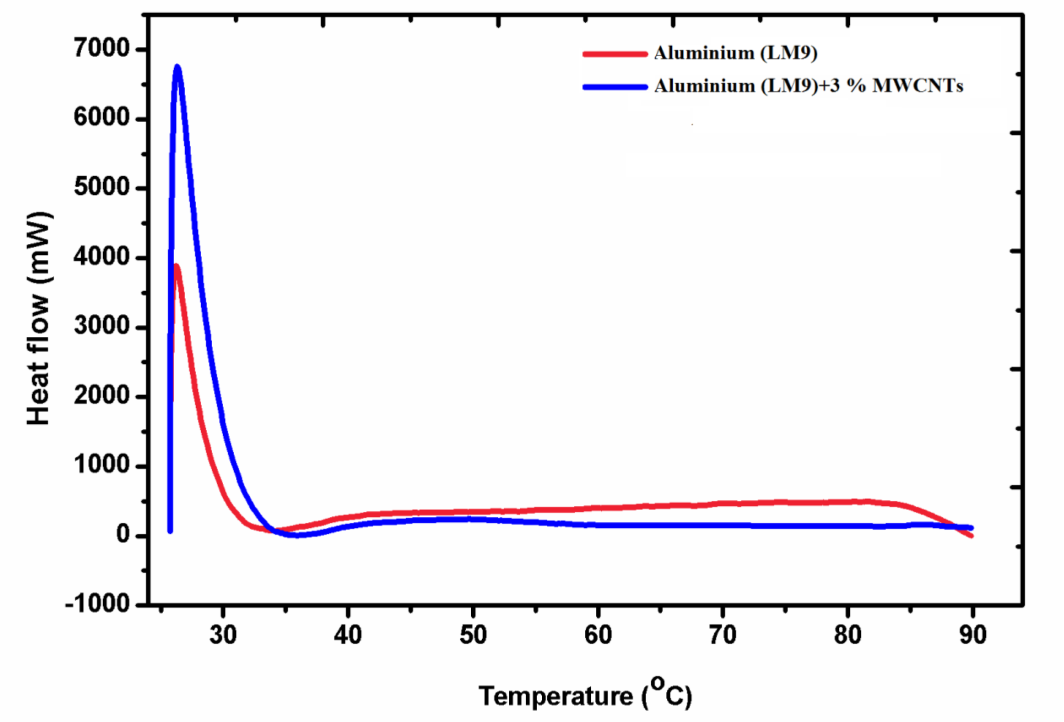

Figure 3: DSC Curve Depicting Variation of Heat Flow with Temperature.

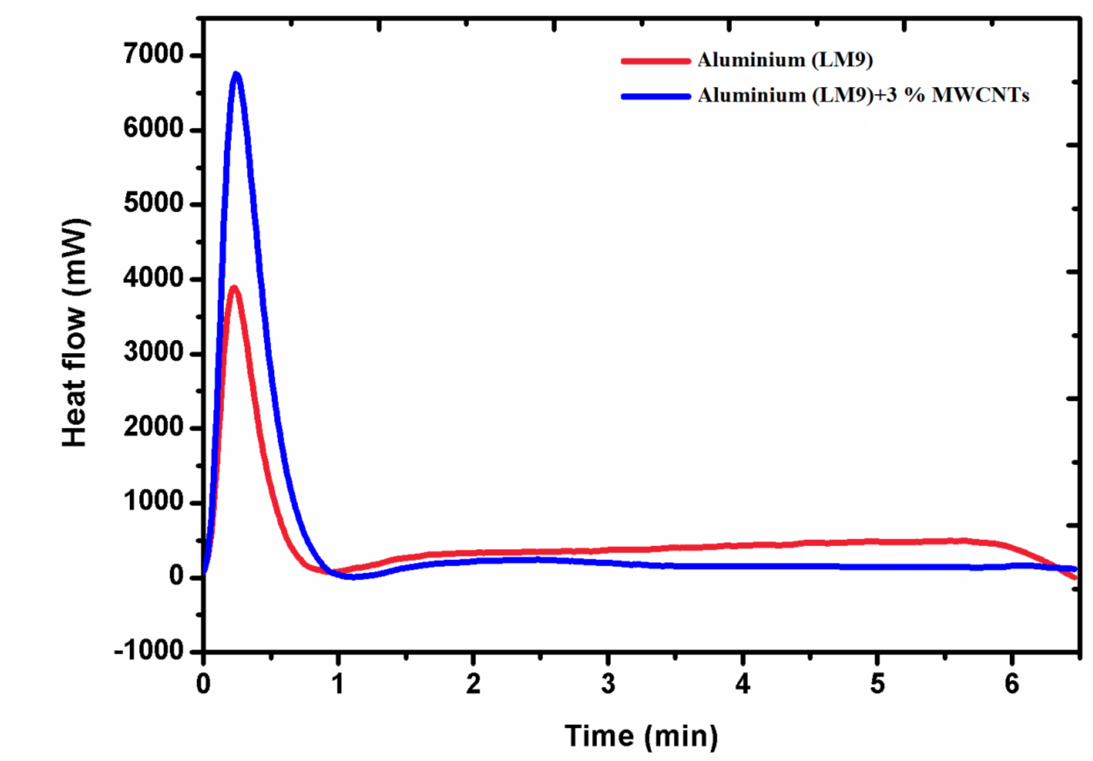

Figure 4: DSC Curve Depicting Variation of Heat Flow with Time

3.4 Thermal Conductivity Variation with MWCNTs as Reinforcements

Figure 5 depicts the variation of thermal conductivity of Aluminium and Aluminium – MWCNTs composites for varying

percentage of weight fraction of multi walled carbon nanotubes. It can be found that there is a lessening of thermal conductivity as the weight fraction increases. Furthermore, it can be established that the influence of weight fraction on the thermal conductivity improvement is also noteworthy. The results of improved relative density of composites would result in poor mobility of electrons and hence decrease in thermal conductivity.

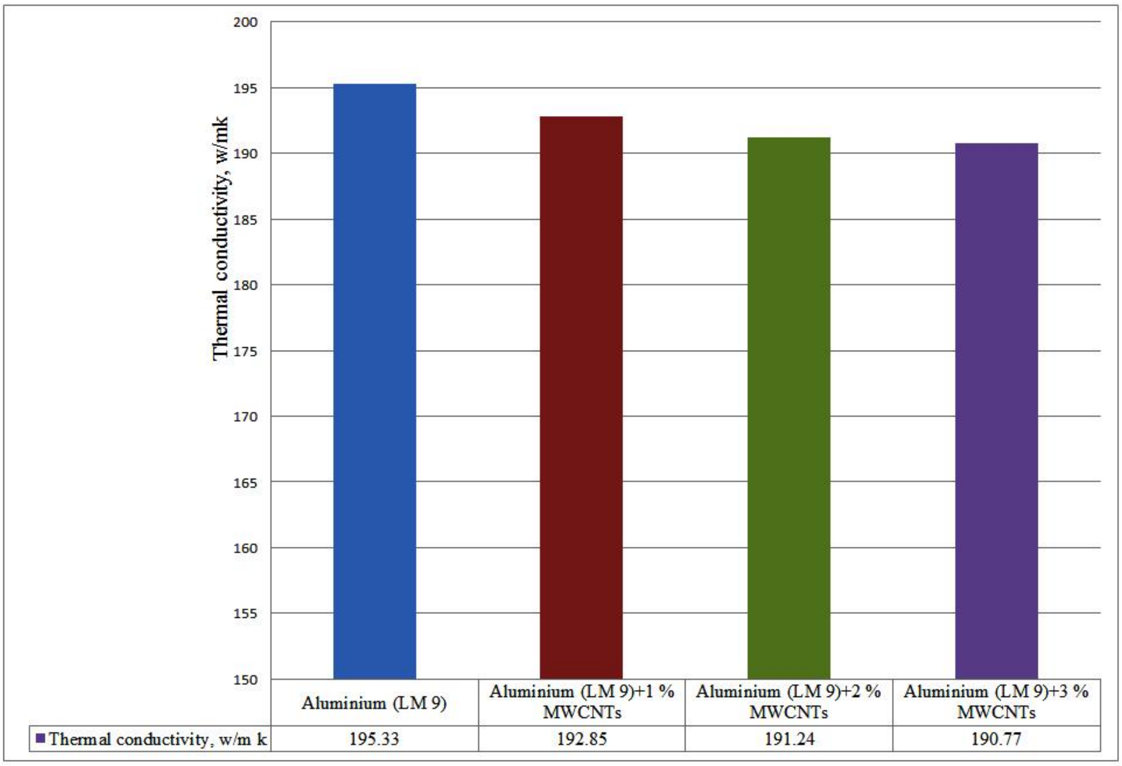

Figure 5: Thermal Conductivity if Base Metal and Aluminium Composites.

4 CONCLUSIONS

From the studies, the following conclusions has been arrived:

- The aluminium – MWCNT metal matrix composites prepared with stir casting technique resulted in fine microstructure.
- Pre-processing of MWCNTs could result in better distribution of MWCNTs in the aluminium.
- The strength of composites in terms of hardness has improved with reinforcement of MWCNTs and the influence of mass fraction of MWCNTs is found to be profound in the improvement.
- The thermal performance of aluminum – MWCNTs nanocomposites is similar to base aluminium with DSC curves getting super imposed.
- There is slight reduction in the thermal conductivity of the composites compared to base aluminium due to improvement in the density of the structure.

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